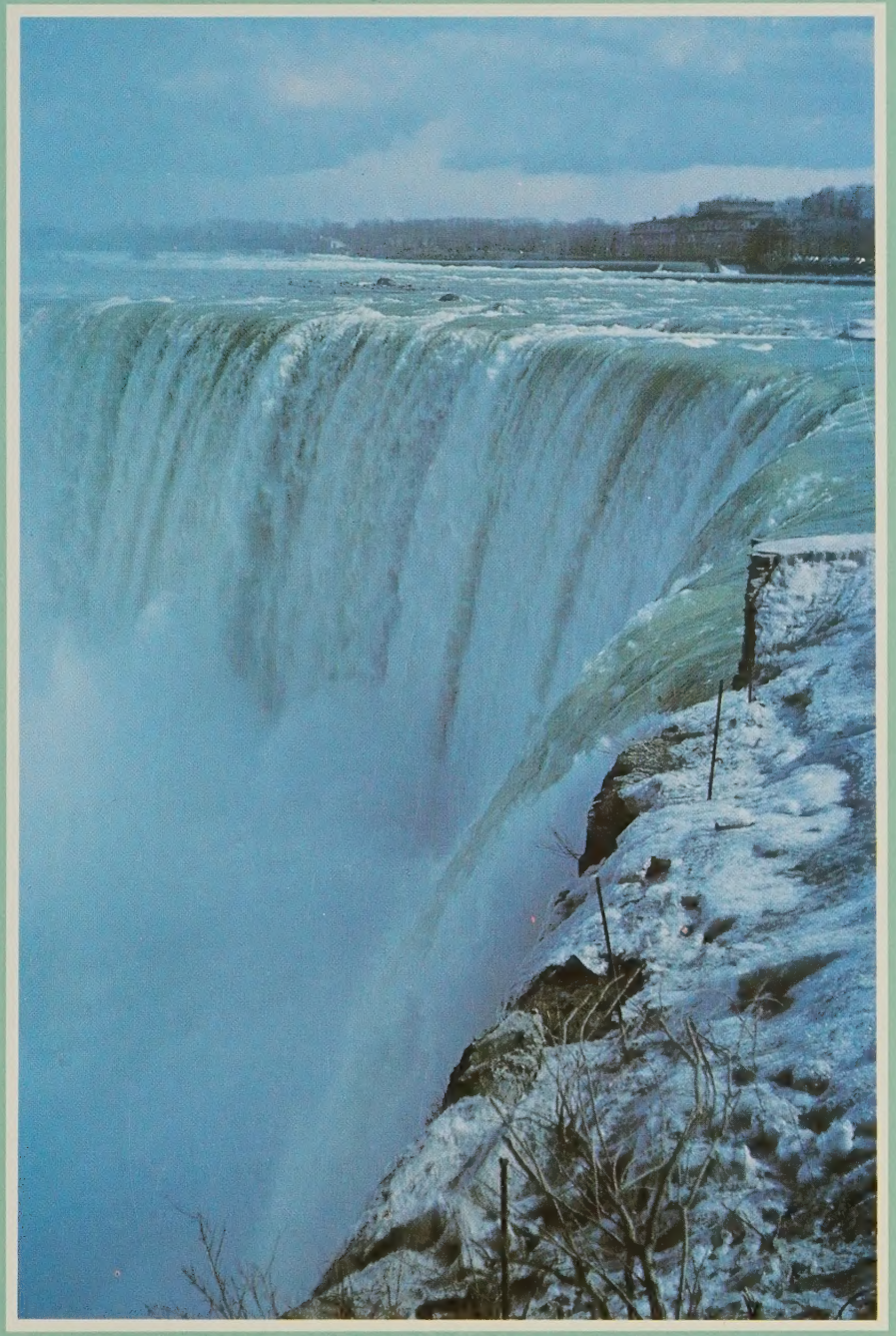
ROM ENCOUNTER SERIES

# The Niagara River

Walter M. Tovell



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# Some early thoughts

I could not conceive how it came to pass, that four Great Lakes, the least of which is 400 Leagues in compass, should empty themselves one into another, and then all centre and discharge themselves at this Great Fall, and yet not drown a good part of America.

*Louis Hennepin* (1640–1701?)

An engraving from Father Hennepin's book *Nouvelle découverte d'un très grand pays situé dans l'Amérique.* The engraving was based on Father Hennepin's recollections and is fanciful and exaggerated.

The words with which this story begins were written about 300 years ago by the first European to describe the Niagara Falls. Father Louis Hennepin was a Recollet missionary friar from France, who served as chaplain to an expedition of explorers under the Sieur de La Salle. In 1678 he followed a thunderous sound and a pillar of mist to their source—and came upon one of the seven natural wonders of the modern world.

The awe in Father Hennepin's account of his first sight of the great cataract, cascading thousands of tonnes of water into a picturesque gorge, has been echoed and re-echoed through the years. Long before they became a favourite of honeymooners, the Niagara Falls were attracting visitors from many lands, and from the beginning they challenged scientists and philosophers and inspired artists and poets.

. . . I should wander here
In musing awe; should tread this wondrous world,
See all its store of inland waters hurl'd
In one vast column down Niagara's steep; . . .

*Thomas Moore* (1779–1852)

The power and form of the Niagara Falls are only part of their fascination; beyond lies the history of the river, the rocks, and the gorge. When and how were they formed? About a hundred years after Father Hennepin discovered the falls, another early visitor from France marvelled:

It is surely a wonderful fact in geography, that a river, very near 2,500 feet wide, and generally fifteen in depth, should find the level of its channel suddenly sink beneath its stream, and should throw down its entire mass of water, from a height of a hundred and forty-four feet, into a channel through which it pursues its subsequent course, where the spectator can discover no hill or ridge that could once have restrained or blocked up its passage.

The broken white line indicates the estimated position of the Canadian Falls when Father Hennepin came upon them in 1678.

We now know that in the beginning, following the last withdrawal of the glaciers, an ancestral Niagara River poured over the rim of the Niagara Escarpment just above the site of the present village of Queenston. Gradually its tumbling waters eroded a channel into the bedrock, to form the gorge and move the falls closer and closer to Lake Erie. Thus the evolution of the Niagara River, the falls, and the 11-km gorge are part of a long-continuing process, but for nearly two centuries the time involved in the cutting of the gorge was the subject of debate.

In the 17th and 18th centuries, many people claimed that they could determine exactly when the earth had been created. From biblical evidence, a distinguished Irish archbishop, James Ussher, calculated the date as October 23, 4004 B.C.—at 9 A.M.! Could the Niagara Gorge have been cut in that short period? Robert McCauslin, who settled at Niagara Falls in 1780, was doubtful, and he set out his argument in a speech to the American Philosophical Society in 1789.

It is universally believed that the cataract was originally at this ridge [*the Niagara Escarpment above Queenston*], and that it has by degrees worn away and broke down the rock for the space of these six or seven miles. Some have supposed that from these appearances, conjectures might be formed of the age of this part of the world. If we adopt the opinion of the Falls having retired six miles, and if we suppose the world to be 5,700 years old, this will give about sixty-six inches and a half for a year, or sixteen yards and two-thirds for nine years, which I can venture to say has not been the case since 1774.

When religious beliefs and geological theory came into conflict, the former seemed to prevail. Was it not more likely, Ussher's supporters asked, that the gorge was the result of "terraqueous convulsions" or a single "revolutionizing struggle"—that in fact the entire operation had taken not thousands of years but only a month, or perhaps a day?

Nonetheless, there were some people even then who challenged Ussher's calculation for the age of the earth. As early as 1790 one man estimated the age of the falls as 55 440 years, and that figure was adopted as the basis for calculating the age of the earth. A little later another theoretician used the estimated age of the falls to determine a period of 36 960 years "since the first rain fell upon the earth".

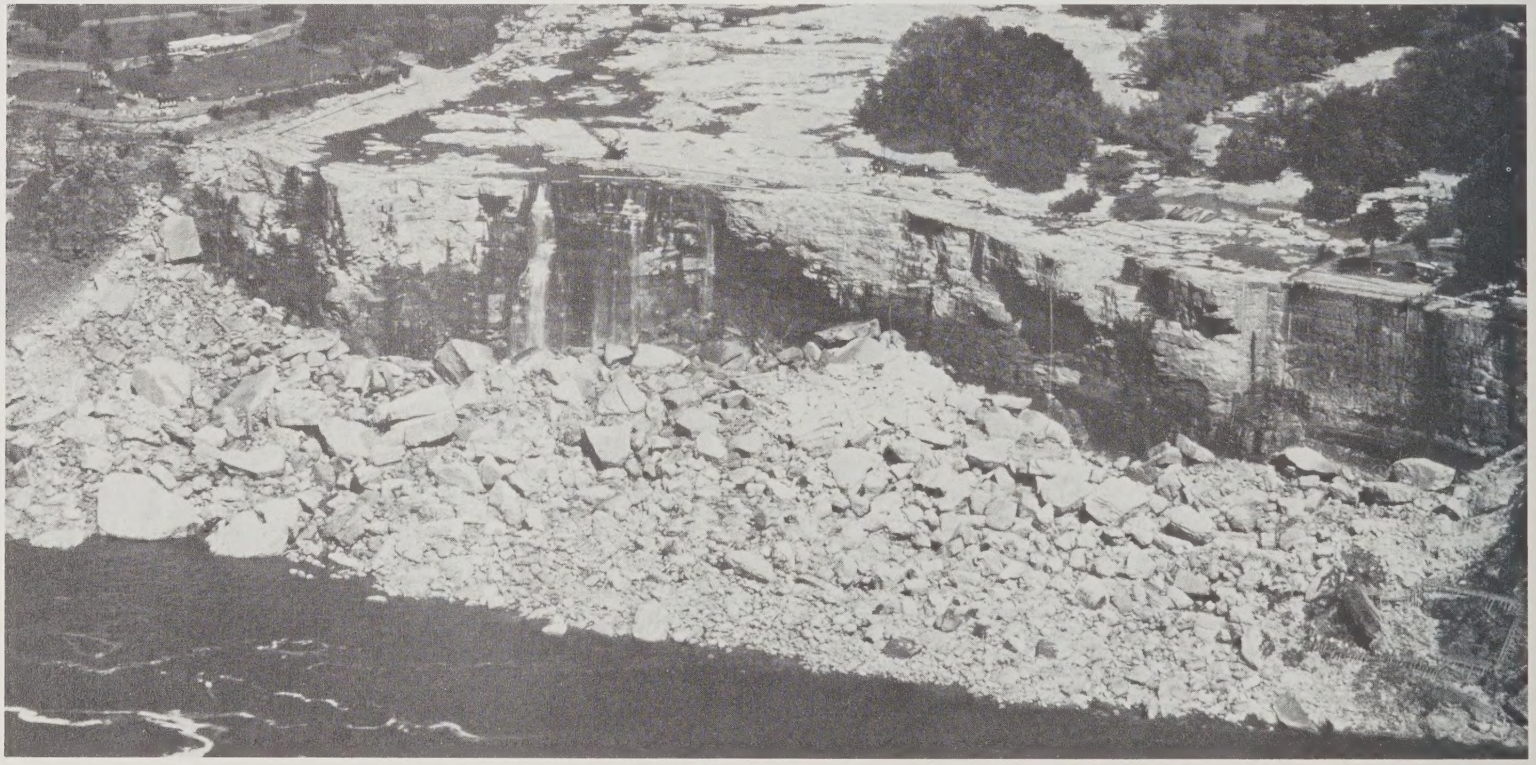
The first accurate portrayal of the falls was made in 1827 by Captain Basil Hall, a British army officer. Captain Hall used a *camera lucida,* which projected an image of the falls directly onto his drawing paper.

## How was the gorge formed?

The controversy about the gorge eventually was resolved by Charles Lyell, a British scientist who was one of the fathers of modern geology. In 1841 he visited Niagara Falls and demonstrated beyond dispute, from observations of the rocks at the falls and along the river, that the cascading waters had eroded the gorge, causing the falls to recede from the edge of the escarpment at Queenston to their present position. This recession, he said, might have required 35 000 years, but the Niagara Escarpment was much older than that.

Lyell's conclusions were supported by an equally distinguished pioneer American geologist, James Hall. His independent studies for the State of New York included the first accurate survey of the rim of the falls to establish a basis for measuring the rate of recession. In 1843 Hall, too, reported that the river had been the great agent in excavating the gorge, and he agreed with Lyell that the gorge was very young in geological time.

The erosion of the gorge, which still goes on, was governed by the alternating layers of hard and soft rock that form its walls. At the edge of the falls today only two units of rock are exposed: layers (called *strata*) of hard dolostone—the Lockport dolostone—and directly beneath them layers of the softer Rochester shale. Since the



The talus at the foot of the American Falls was clearly revealed when the falls were dewatered in 1969.

dolostone is much less susceptible to the erosive action of the tumbling waters than the softer shale, in time the rim of the escarpment is undermined and abruptly collapses in great rockfalls. The cataract then moves a step further upstream, still maintaining a vertical drop (Figure 1). This process of erosion is called *sapping,* and other factors contribute to it. Water working along the cracks and joints in the rocks freezes and expands during the winter, hastening the collapse of the rim. An increase in the volume of water cascading over the rim increases the rate of sapping; a decrease in volume has the opposite effect.

The chunks of rock that fall to the base of the falls form a heap, called *talus.* The talus at the foot of the American Falls was dramatically exposed when the falls were dewatered in 1969. Although formation of talus is usually a gradual, ongoing process, from time to time large rockfalls occur: one in 1956 destroyed part of the Schoellkopf Power Plant at the river's edge downstream from the Rainbow Bridge.

Along the gorge below the falls, the layers of rock underlying the Rochester shale are exposed. Some of the strata are hard and form ledges and cliffs; some are softer and form gentler slopes. At the mouth of the gorge, upstream from Queenston, all the strata of the escarpment are visible. Here it is a simple feat of the imagination to envisage the falls in their original position at the time that they started cutting the gorge.

As the gorge was eroded, the falls receded, and their successive profiles varied. Sapping occurred at each point along the gorge where a hard layer of rock overlies a softer layer. For example, in the vicinity of the Niagara Glen (Figure 4) there may have been as many as three separate drops at one time. The present profile of the cataracts began to develop about 2000 years ago, when the gorge had already been cut back to the vicinity of the Rainbow Bridge (Figure 4).

A rockfall in July 1954 caused the collapse of Prospect Point, just north of the American Falls.

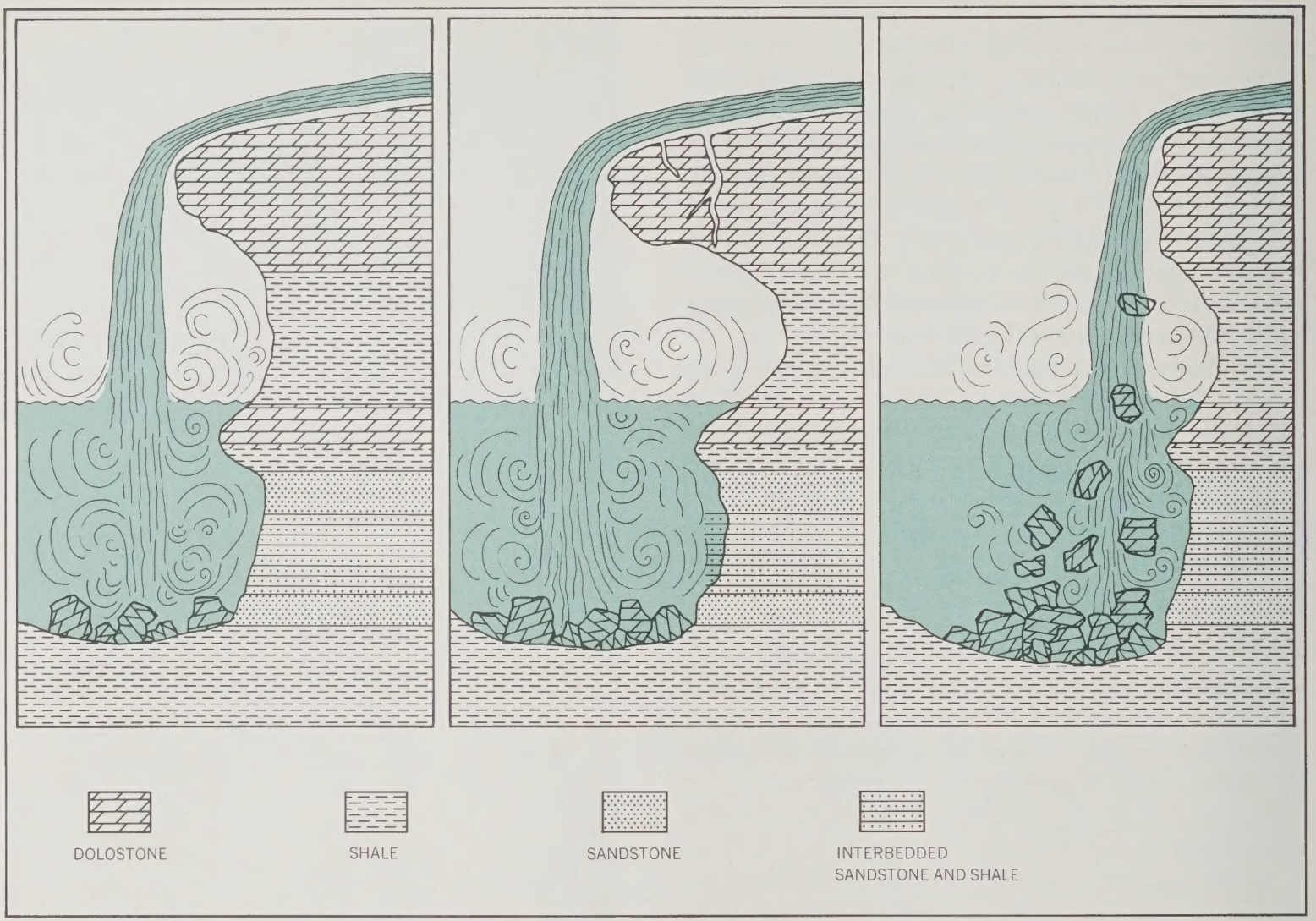
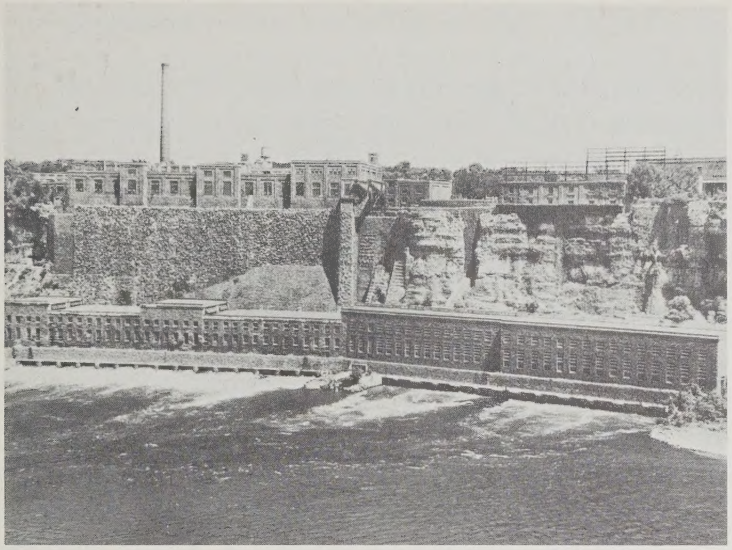


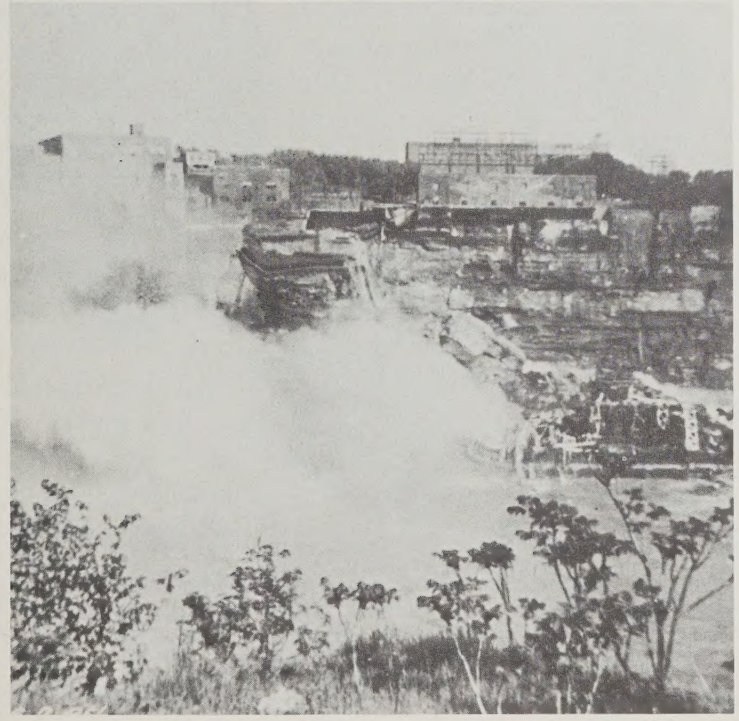

Figure 1 The sapping process. Notice how the hard dolostone is undermined as the swirling water wears away the softer shale. The joints and fractures in the dolostone aid the process.

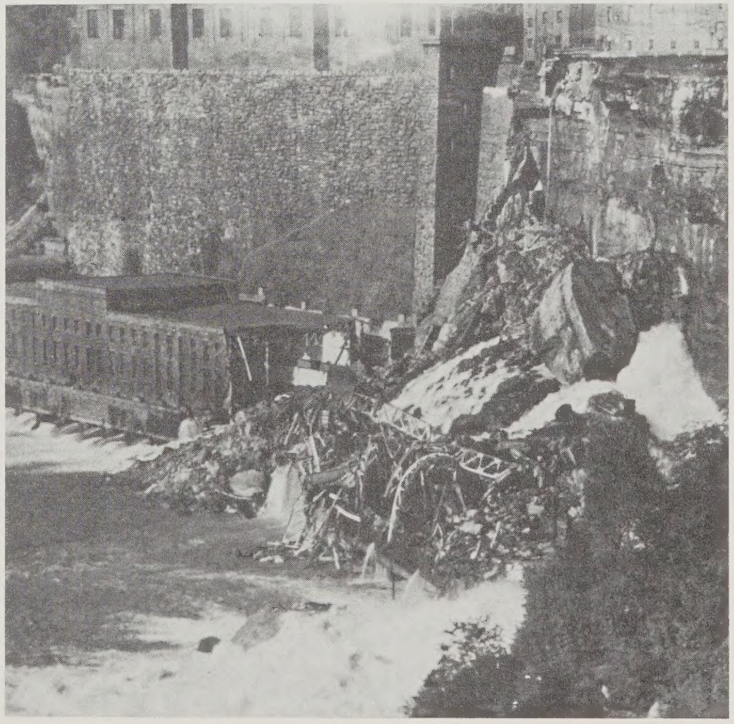


Left: The Schoellkopf Power Plant at the edge of the Niagara River in New York State.

Below left: The power plant at the time of the rockfall in June 1956.

Below right: The power plant after the rockfall.





# The rocks of the gorge

The rocks exposed almost continuously along both sides of the Niagara Gorge occur in strata of dolostone, limestone, shale, siltstone, and sandstone. Their colours range from red to buff and mottled green to grey, and the colours appear to change in different lights, adding interest and beauty to the vistas.

The rocks are of sedimentary origin, that is, the particles of which they are composed were deposited in bodies of water. In time, through natural processes, the loose, unconsolidated particles became cemented together to form solid rocks. Most of these rocks contain fossils, which have been identified as being the remains of ancient marine life. Some forms are extinct: among these are trilobites, the forerunners of lobsters and crabs; and stromatoporoids, colonial animals akin to corals in that they built reefs. Other fossils indicate that the direct ancestors of modern life-forms, including snails, clams, and brachiopods (animals that look like clams but are quite different in their anatomy), lived in these ancient seas (Figure 2).

Geologists have subdivided the layers of sedimentary rock into several formations; each formation is identified by a geographic name (Figure 3, photo p. 12). For example, the red shales are named for Queenston, Ontario, where they were first studied. The exposed thickness of

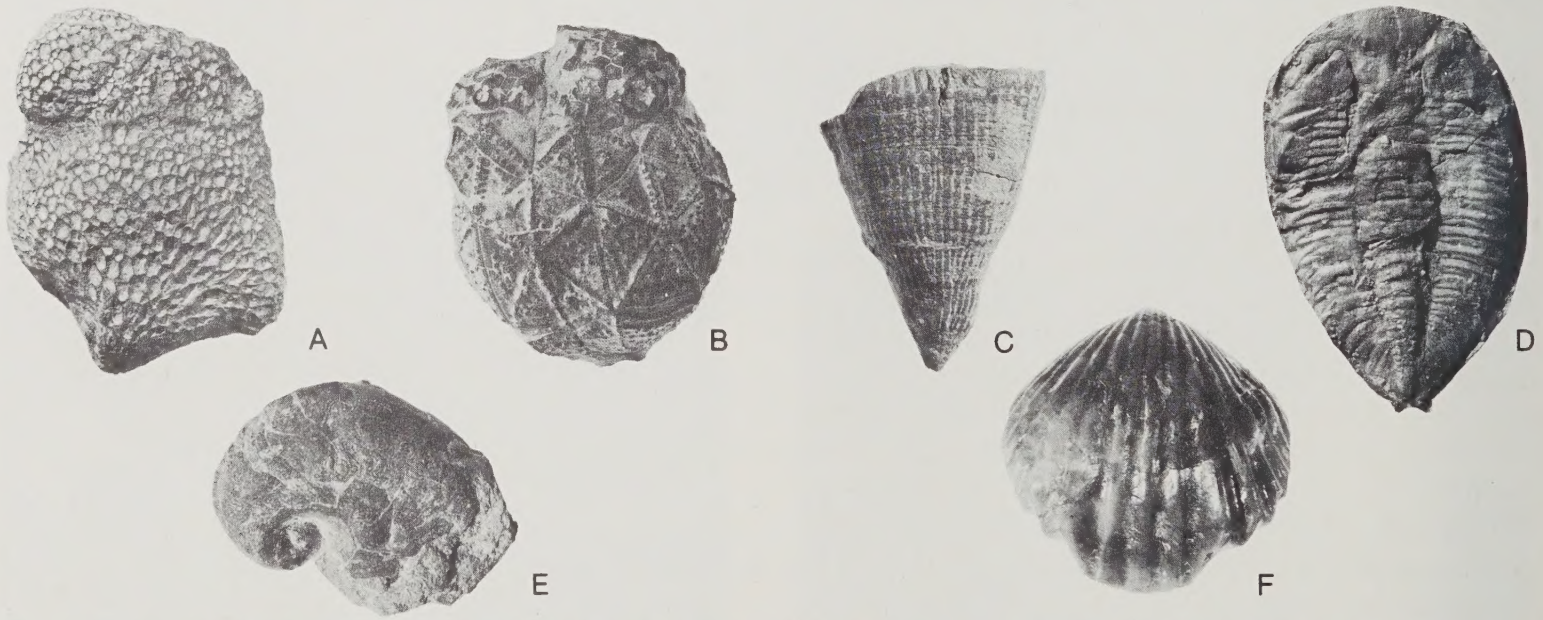



Figure 2 Some fossils found in the rocks of the Niagara Gorge, from the collections of the Royal Ontario Museum.

A Colonial coral, *Favosites forbesi* (x 1.3)
B A relative of the sea lily, *Caryocrinus ornatus* (x 1)
C Cup coral, *Enterolasma caliculum* (x 1.6)
D Trilobite, *Dalmanites limulurus* (x 1)
E Snail, *Platyceras niagarense* (x 1.75)
F Brachiopod, *Camarotoechia obtusiplicata* (x 2)

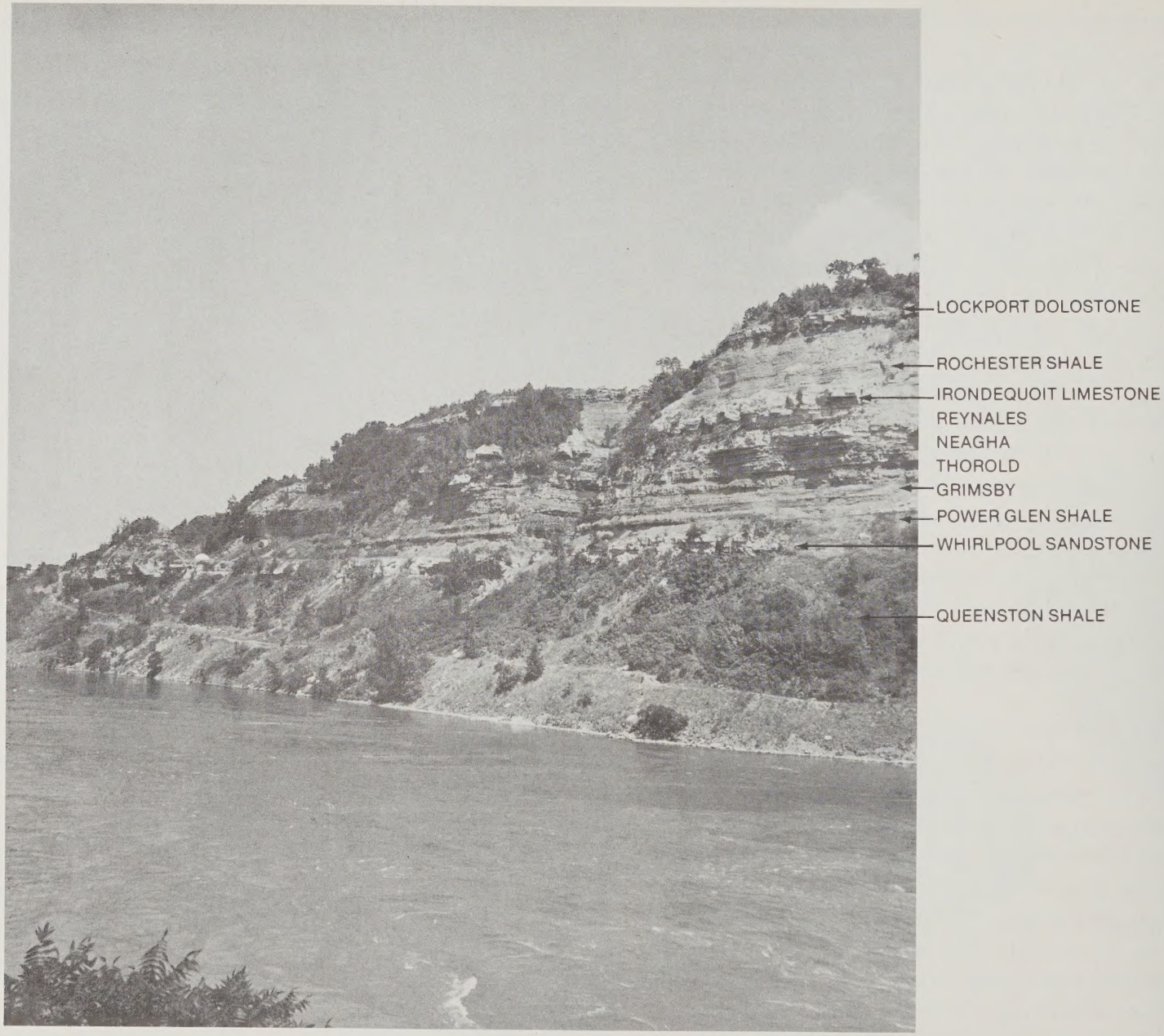
some formations varies, while that of others remains constant. If you follow the river southward from Queenston to the falls, you can easily observe changes in the formations. The Queenston shale, which is highly visible along the banks of the river north of the edge of the escarpment, disappears just below the Whirlpool Rapids. The Lockport dolostone, the top stratum of the gorge, is very thin at the north end of the gorge above Queenston, while at the falls it is about 25 m thick. The Rochester shale, in contrast, maintains an almost constant thickness.

Three factors account for the variations. Between Queenston and the falls, the river rises 30 m, so that even if the layers of rock were perfectly horizontal, they would disappear from view below water level. Since the layers slope southward at the rate of 4 m/km, they disappear even faster beneath the water. Finally, erosion prior to and during glaciation caused variations in the thickness of the Lockport dolostone. It is for these reasons that right at the falls only the Lockport dolostone and Rochester shale are exposed, but the older formations are present beneath the water line. In fact, the plunging waters of the Canadian Falls have excavated the river bottom into the Queenston shale.

Both Lyell and Hall realized that the rocks exposed in the gorge of the Niagara River were considerably older than the river itself, but at the time of their investigations the science of geology was not advanced enough to permit them even to guess at the age of the rocks. All they knew was that the rocks were "monuments to time". Today geologists assign the rocks to the Ordovician and Silurian periods of the standard geological time scale (Table 1), and place their age at between 450 and 400 million years. The contact between the Queenston shale and the overlying Whirlpool sandstone is the contact between the Ordovician and Silurian periods.

*Table 1 Geological Time Scale*
*The Calendar of Earth History*

| EON | ERA | PERIOD | BEGAN MILLION YEARS AGO |
|---|---|---|---|
| PHANEROZOIC | **Cenozoic** | Quaternary — Recent, Pleistocene | 2 |
| | | Tertiary | 65 |
| | **Mesozoic** | Cretaceous | 136 |
| | | Jurassic | 190 |
| | | Triassic | 225 |
| | **Palaeozoic** | Permian | 280 |
| | | Pennsylvanian | 325 |
| | | Mississippian | 345 |
| | | Devonian | 395 |
| | | Silurian | 430 |
| | | Ordovician | 500 |
| | | Cambrian | 570 |
| PRECAMBRIAN | | | |
| | | | 3700± |
| Formation of crustal rocks | | | |
| Origin of the earth | | | 4600± |

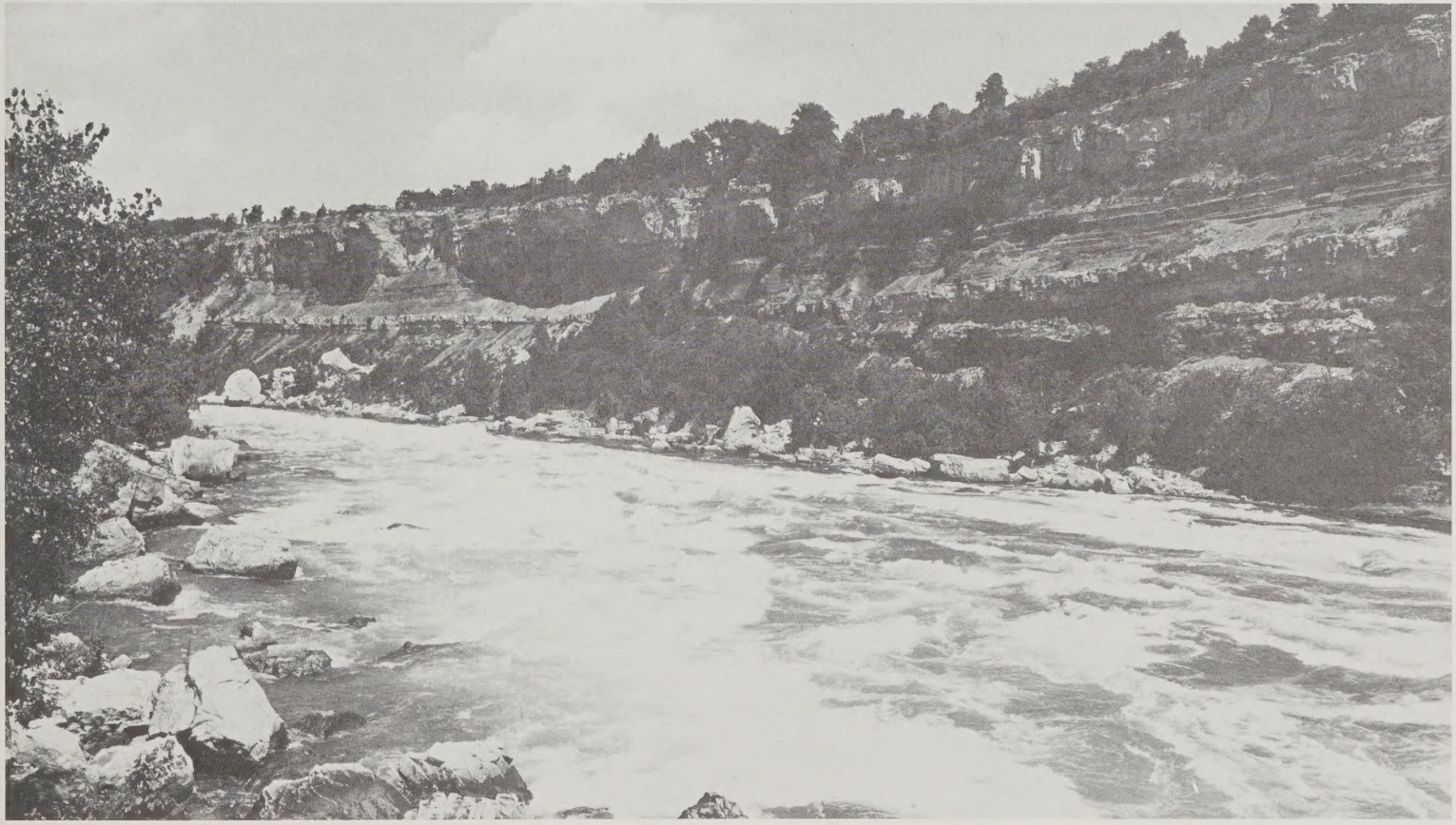



View of the east bank of the Niagara River from below Locust Grove showing the rock formations exposed along the gorge at the edge of the Niagara Escarpment.

# The origin of the Niagara River

At first geologists concentrated their studies on the origin and age of the gorge, but what about the origin of the Niagara River itself? This swift-flowing body of water connecting Lake Erie and Lake Ontario carries as much water at its head as at its mouth, without the marked seasonal variations in volume of other large rivers. Except for the gorge, it has no well-defined valley, and it has no significant tributaries. It is, as Father Hennepin noted, "such a big river with no mountains".

Until the last quarter of the 19th century, the origin of the Niagara River remained a mystery. Then the river's evolution was fitted into the geological history of North America, and in particular into the chapter of continental history that encompasses the period of glaciation—the Pleistocene Epoch or the Great Ice Age. As the concepts of the glacial age developed, so did the realization that the present Great Lakes and their connecting rivers evolved with the final retreat of the ice sheet.



The Whirlpool Rapids of the Niagara River.

About a million years ago, massive glaciers spread out to cover most of the North American continent north of the 40th parallel. Eventually they retreated, only to advance again. The cycle occurred four times in all, but most of what we know about the glacial history of southern Ontario relates to the last advance and the last retreat. The final withdrawal in eastern North America began about 20 000 years ago, from south of Lake Erie. As the ice fields withdrew, the meltwaters became trapped between the high land around each lake basin and the margins of the glaciers. Since these margins changed continuously as the ice melted or re-advanced, there was in each lake basin a succession of changing lakes, from which evolved the ones we know today. The shifting pattern of lakes was accompanied by changes in the rivers connecting them.

Sometimes the waters of the upper lakes discharged through Lake Erie, but at other times they did not, and thus the volume of water flowing between the Erie and Ontario basins varied. As the flow increased or slackened, so did the power of the waters to erode a channel. The narrow and broad sections of the Niagara Gorge are in fact a record of the varying volume of water that flowed over the falls as the gorge developed.

Immediately after the Niagara region was uncovered, a lake—called Lake Tonawanda—developed between the escarpment and Lake Erie. The northern border of this body of water lay a few kilometres south of, and parallel to, the escarpment. Lake Tonawanda was an unusual lake in that it stretched 93 km east-west and had an average depth of 10 m. It had at least five outlets or spillways, which drained northward over the escarpment into the Lake Ontario basin. The westernmost outlet was the Lewiston Spillway which eventually became the Niagara River, after the other spillways were abandoned.

## The buried gorge

One puzzle remained unsolved—the origin of the buried gorge that runs from the Whirlpool to a large embayment in the escarpment near the village of St. David. The clue to its existence, first noted by Lyell, is the fact that no bedrock is exposed in the northwest wall of the Whirlpool basin. Years after Lyell discovered the buried gorge, drilling confirmed that it extended northward. Recently a geophysical survey and further drilling between the Whirlpool basin and Lake Ontario were undertaken. Data from these investigations indicate that an ancient river, predating the present Niagara River, once flowed between the Whirlpool and the Lake Ontario basin. It eroded a channel into the bedrock, and that old channel became filled with deposits of gravels, sands, and clays, some of which were of glacial origin. Material of glacial origin has also been identified from borings for the foundations of the railway bridge just upstream from the Whirlpool Rapids Gorge. Thus it appears that the buried St. David Gorge once extended well upstream, and that the present Niagara River has re-excavated part of it (Figure 3).

This interpretation of geological evidence throws new light on the history of the Niagara Gorge: it suggests that an ancient river once flowed through the present Whirlpool Rapids Gorge and the buried St. David Gorge into the Lake Ontario basin. With a glacial re-advance, this path became filled with mud, gravel, and clay. Then, with the final retreat of the ice, the present Niagara River (initially the Lewiston Spillway) cut the gorge back to the Whirlpool, re-excavated the present Whirlpool Rapids Gorge, and finally cut out the Upper Great Gorge, at whose head are the present falls.

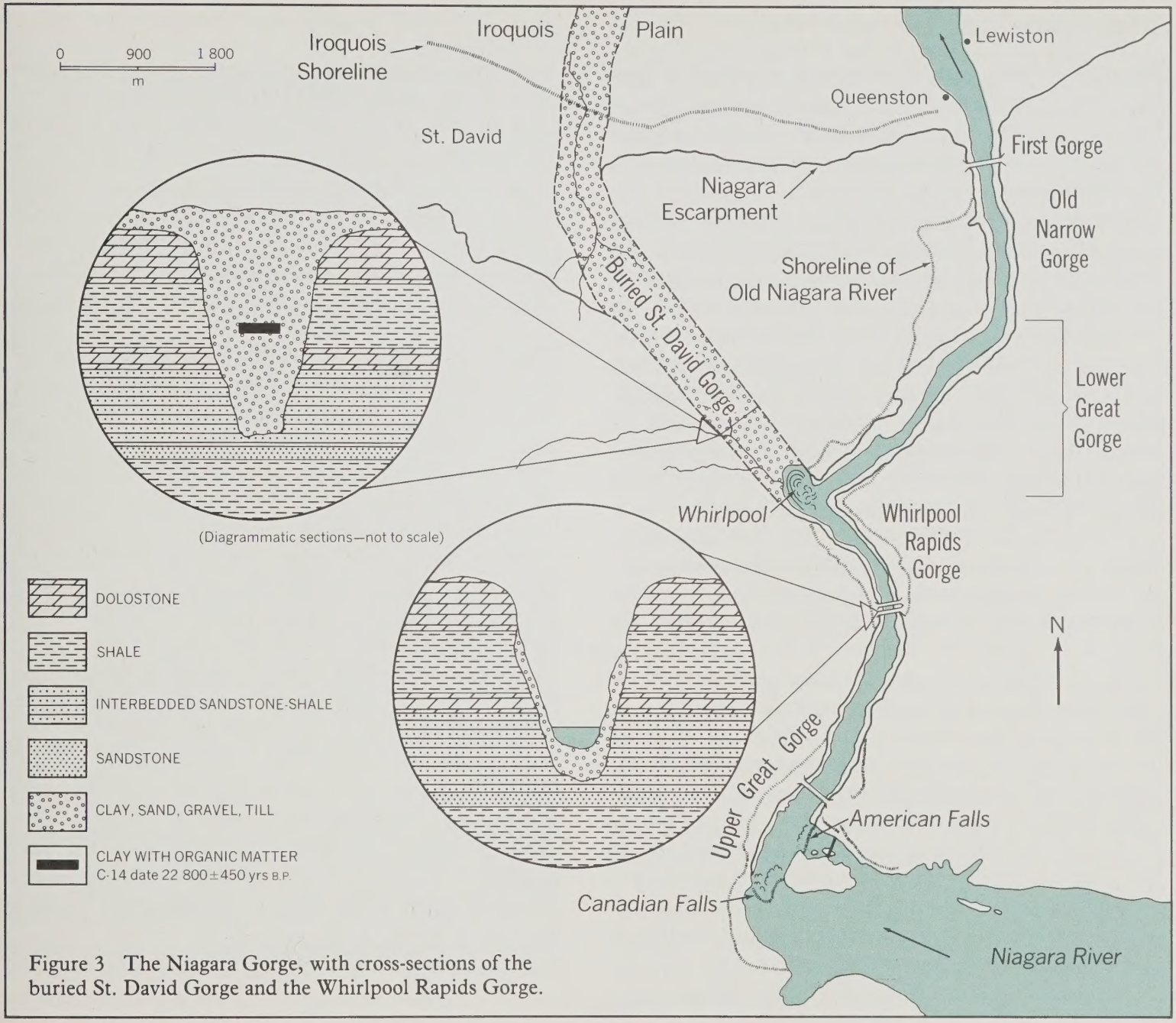



Figure 3 The Niagara Gorge, with cross-sections of the buried St. David Gorge and the Whirlpool Rapids Gorge.

# How long ago?

Perhaps no other natural phenomenon related to geological events has kindled such consciousness of time as has the recession of the Niagara Falls. The time required for this recession has been guessed, estimated, measured, and deduced, with varying results.

First of all, the use of the gorge as a geological clock requires knowledge of the rate of recession of the falls, and the rate of recession can be determined properly only from accurate surveys of the rim. The first such survey was made under the direction of James Hall in 1842. A second survey in 1875 established the fact that the falls had receded and permitted the calculation of an annual rate of recession for the 33-year period; until that time no measured rate was available. Since 1875 additional surveys have been undertaken and the rates of recession determined; some of the results appear in Table 2.

To estimate the time required for the excavation of the Niagara Gorge, based on measured rates of recession, several factors must be taken into consideration. The most important of these include the height of the cataract, the width of the river, the thickness of the Lockport dolostone, the variations in the resistance to erosion of the underlying strata, and the volume of water cascading over the falls. This last factor is very difficult to evaluate because during the time that the falls were excavating the gorge, the volume of water delivered from the upper Great Lakes varied. It is no wonder then that estimates for the time required for the excavation of the gorge have ranged from 5000 to 100 000 years! The problem is complicated even further by the fact that the Whirlpool Rapids Gorge was re-excavated through the removal of unconsolidated glacial deposits. F.B. Taylor and E.M. Kindle, two distinguished geologists working early in this century, stated

*Table 2 Some Published Rates of Recession of Niagara Falls*

| FROM | TO | INTERVAL IN YEARS | AMERICAN FALLS M/YR | CANADIAN FALLS M/YR |
|---|---|---|---|---|
| 1842 | 1875 | 33 | 0.23 | 0.61; 1.21–1.34 |
| 1842 | 1890 | 48 | 0.20 | 0.66 |
| 1842 | 1905 | 63 | very little | 1.16; 1.28; 1.61 |
| 1842 | 1911 | 69 | — | 1.52 |
| 1875 | 1886 | 11 | 0.03 | 0.57 |
| 1875 | 1905 | 30 | — | 1.70–2.01 |
| 1886 | 1890 | 4 | 0.50 | 1.52 |
| 1905 | 1927 | 22 | very little | 0.70 |

*The Canadian Falls have now been "stabilized" by anti-erosion measures, and the recession is said to have been reduced to 0.3 m/yr or less.*

in 1913 that the making of the gorge may have taken from 20 000 to 30 000 years or possibly 35 000, and added: "It is not believed that more precise estimates can have any greater value." In other words, the method of calculating age based on the rate of recession can give only an approximate age for the Niagara Gorge of between 10 000 and 50 000 years. By 1931, 25 000 years was accepted as a "convenient" figure.

The discovery in 1950 of Carbon-14—a radioactive form of carbon—as a dating technique for recent geological events paved the way for a new and more precise method of establishing when the Niagara River came into being, and how long it has taken the falls to recede from their original position above Queenston. With this technique, a piece of fossil wood, or other organic matter found in a deposit, can be dated with some certainty, if it is less than 40 000 years old. Carbon-14 dates are given in years before the present (B.P.), the "present" being 1950. Organic material found at three places along the old Lake Iroquois shoreline yielded the following Carbon-14 dates: material from excavations for the Hamilton City Hall, 11 510±240 yrs B.P.; material from two localities near Lewiston, 12 660±400 yrs B.P. and 12 080±300 yrs B.P.

*Table 3 Slope of the Niagara River*

| | METRES ABOVE SEA LEVEL | METRES ABOVE LAKE ONTARIO |
|---|---|---|
| Lake Erie | 174.3 | 99.0 |
| Head of Upper Rapids | 170.4 | 95.1 |
| Crest of Canadian Falls | 153.6 | 78.3 |
| Crest of American Falls | 156.1 | 80.8 |
| River level below falls | 105.5 | 30.2 |
| River level at Whirlpool Rapids | 105.1 | 29.8 |
| River level at Whirlpool | 89.3 | 14.0 |
| River level at Queenston | 75.6 | 0.3 |
| Lake Ontario | 75.3 | — |

*All measurements are variable within narrow limits.*

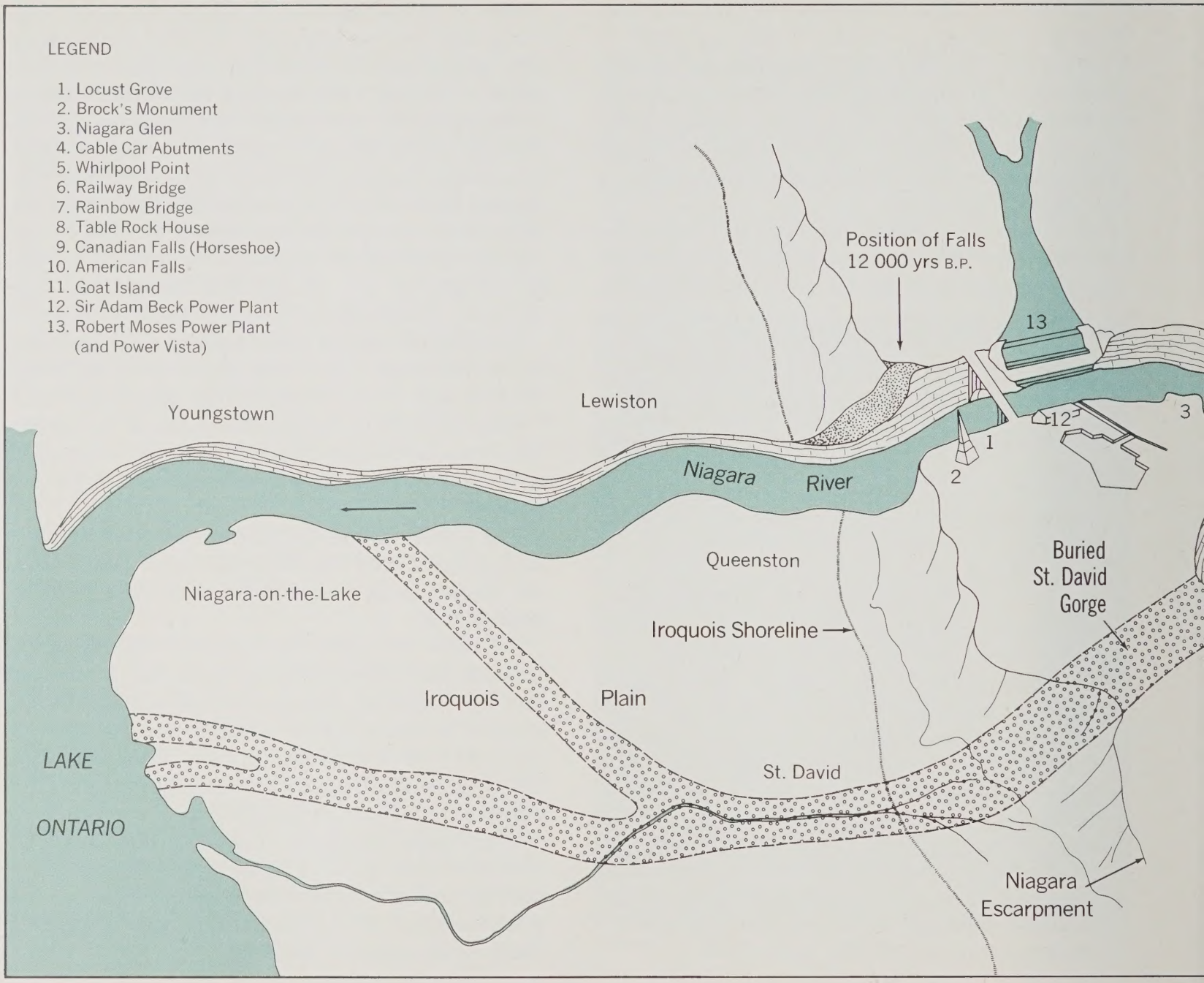
These figures suggest quite clearly that Lake Iroquois was present about 12 000 years ago. Since we know that the excavation of the Niagara Gorge began when Lake Iroquois occupied the Lake Ontario basin, we can assume that it must have required about 12 000 years for the gorge to be excavated and the falls to recede to their present position.

This estimate is substantiated by Carbon-14 dates for ancestral lakes in the Lake Erie basin, and it indicates that the Niagara Gorge was excavated at an average rate of about 1 m/yr.

Carbon-14 also assists in dating the deposits in the buried St. David Gorge. Organic matter taken from a drill hole just north of the Whirlpool at a depth of 45.4 m was dated at 22 800±450 yrs B.P. This can be assumed to be about the time at which the St. David Gorge was filled with unconsolidated deposits, but the time at which it was excavated is still a matter for argument.

The Niagara Falls do not measure the time "since the first rains fell on earth". They do measure the time since thick glaciers retreated from the Niagara Peninsula, which is but a minute fraction of the total time that geologists envisage for the history of the earth.

# The evidence today



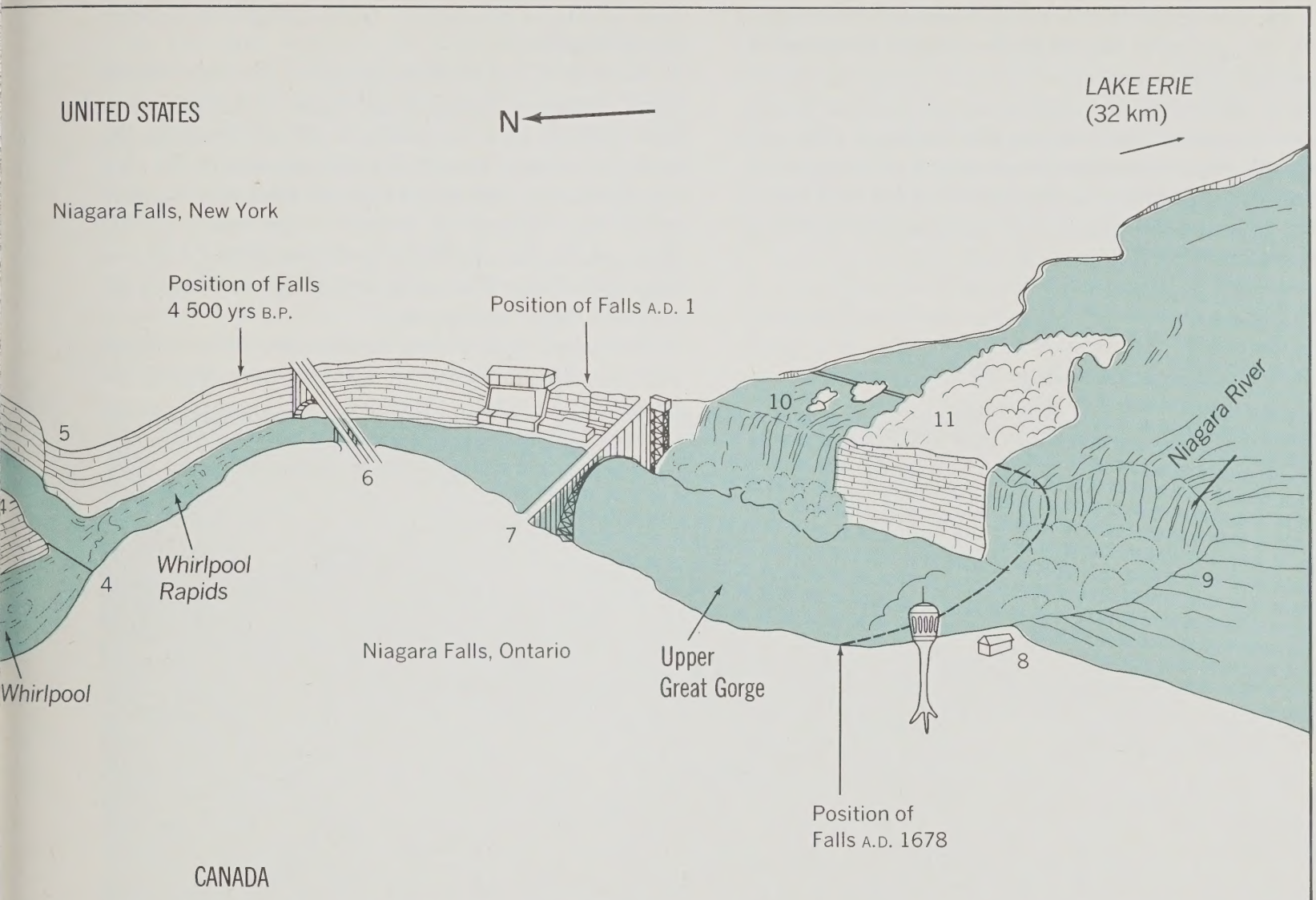



Figure 4 Panoramic sketch of the Niagara Gorge, showing the principal features of the region. The numbers in the section of the text entitled *The evidence today* correspond to the numbers on this sketch.

Urban development now obscures much of the evidence for the geological history of the Niagara River and the gorge, but fortunately it was recorded in great detail in the early 1900s—by exceptionally competent investigators. But excavations for such projects as power plants and sewage disposal facilities are constantly yielding new information. This information is used to refine the history of the river and the estimates of the time involved in the recession of the falls.

### York Road from the village of St. David eastward to Queenston

Nestled in a valley where the brow of the Niagara Escarpment bends southward lies the village of St. David, the point at which the buried St. David Gorge emerges from the escarpment.

From St. David, York Road follows the top of a bluff 5 to 10 m high at the base of the Niagara Escarpment. The base of the bluff is the shoreline of Lake Iroquois, the ancestor of Lake Ontario; the large expanse of flat land stretching away from it, the Iroquois Plain, was the floor of that lake. When Lake Iroquois existed about 12 000 years ago, the area must have looked much like the eastern shore of the Bruce Peninsula, where today the Niagara Escarpment faces Georgian Bay.

The eastern end of York Road intersects the Niagara Parkway, which follows the west (Canadian) side of the Niagara River. About 400 m east of the intersection, the contact between the Queenston red shale and the grey-buff Whirlpool sandstone can be examined.

The Iroquois bluff below York Road.

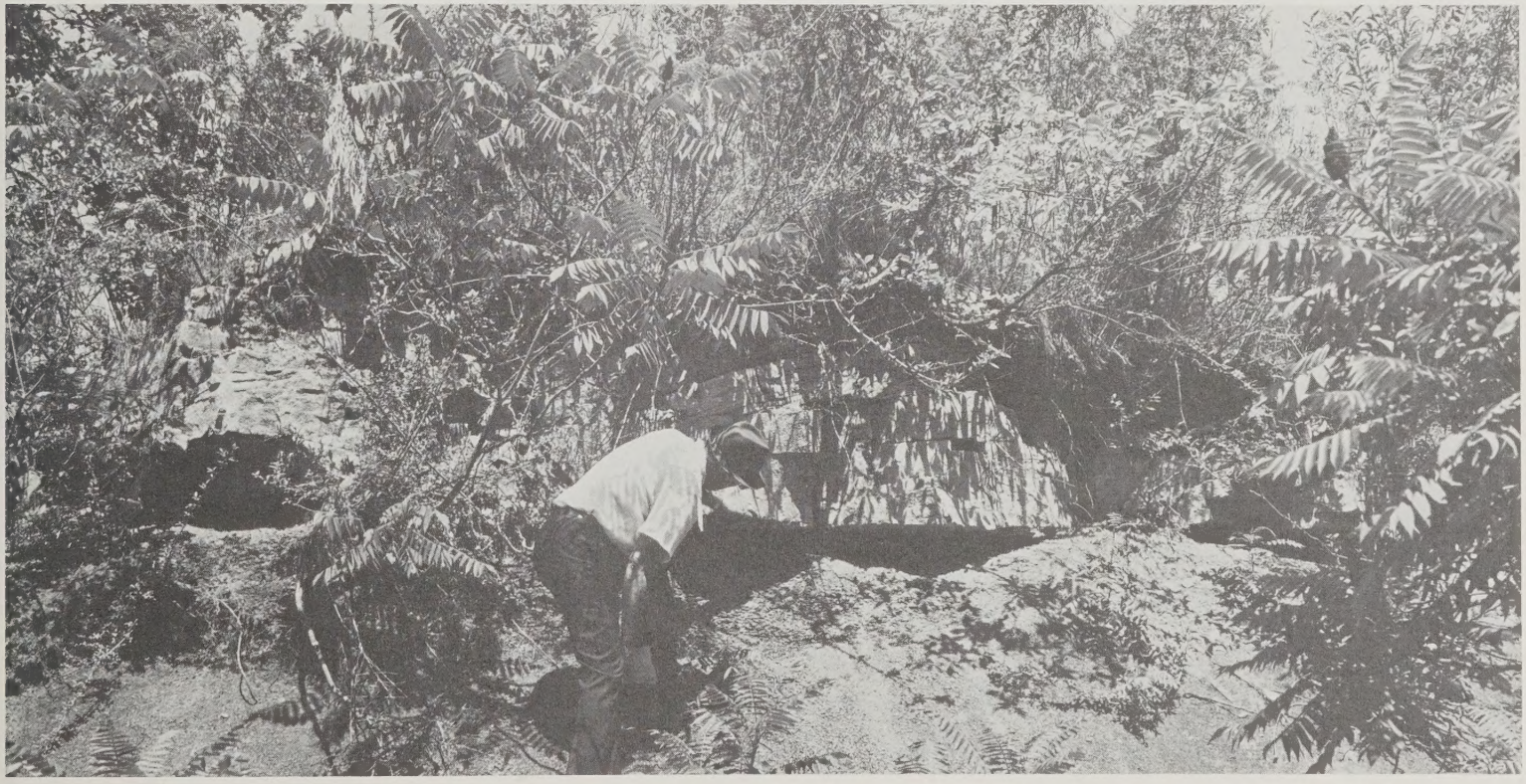
## Locust Grove (1)

This park area bordering the west side of the Niagara Gorge across the Parkway from Brock's Monument (2) is close to the point where the Niagara River began cutting the gorge. From here the rock formations exposed on the east (American) side of the gorge can be seen; the formations are identified in the photograph on page 12. The Whirlpool sandstone extends in an almost level line, beginning well downstream below the edge of the escarpment and continuing upstream, although in places it is obscured by landslides. The continuity of the Whirlpool sandstone indicates that no fault exists at the edge of the Niagara Escarpment.

## The Niagara Glen (3)— Wintergreen Terrace and Foster Flats

About 3 km south of Locust Grove is the Niagara Glen, which encompasses Wintergreen Terrace and Foster Flats. Wintergreen Terrace is a promontory jutting out into the gorge. To reach it from the parking lot, you descend a steep slope about 7 m high, which marks the shoreline of the Niagara River when the falls were downstream.

At the downstream (north) end of Wintergreen Terrace is a precipitous, undercut cliff of Lockport dolostone. From the base of this cliff a dry valley extends towards the river, to an area known as Foster Flats. (Much of this valley has been disturbed by the construction of the road



The contact between the ledge-forming Whirlpool sandstone and the Queenston shale.

on the west side of the gorge.) The northern edge of Wintergreen Terrace marks the actual spot where the waters of the Niagara River once fell in a cataract.

Below the eastern cliff of Wintergreen Terrace is a chaotic accumulation of enormous blocks of weathered dolostone. According to one theory, these blocks are the remains of an island, which divided the Niagara River into two streams some 8000 to 9000 years ago. One branch of the old river flowed over Wintergreen Terrace; the other, closer to the American side, was larger and more powerful, and so cut out the gorge and eventually captured the waters that flowed over Wintergreen Terrace. In time, the island was reduced to rubble.

The locality demonstrates that the Niagara River through the centuries was always broader above the cataracts than below them, just as it is broader above the present cataracts. At one time the old shoreline could be traced almost continuously, but today urban development has obscured it in all but a few places.

### The Whirlpool and the Whirlpool Rapids Gorge

The Whirlpool occurs at a right-angled bend of the Niagara River, after the river has dropped 16 m through the Whirlpool Rapids Gorge. In the Whirlpool, which is at least 38.5 m deep, the water swirls around before the river continues its course downstream.

In the walls of the Whirlpool basin beneath the abutments for the cable car landings (4), the bedrock is exposed. When the water is low, the contact between the Queenston shale and the Whirlpool sandstone is visible where

Wintergreen Terrace, the rocky promontory that juts out into the gorge in the Niagara Glen.

the water leaves the Whirlpool. On the northwest wall of the Whirlpool basin, which marks the beginning of the buried St. David Gorge, no bedrock is exposed.

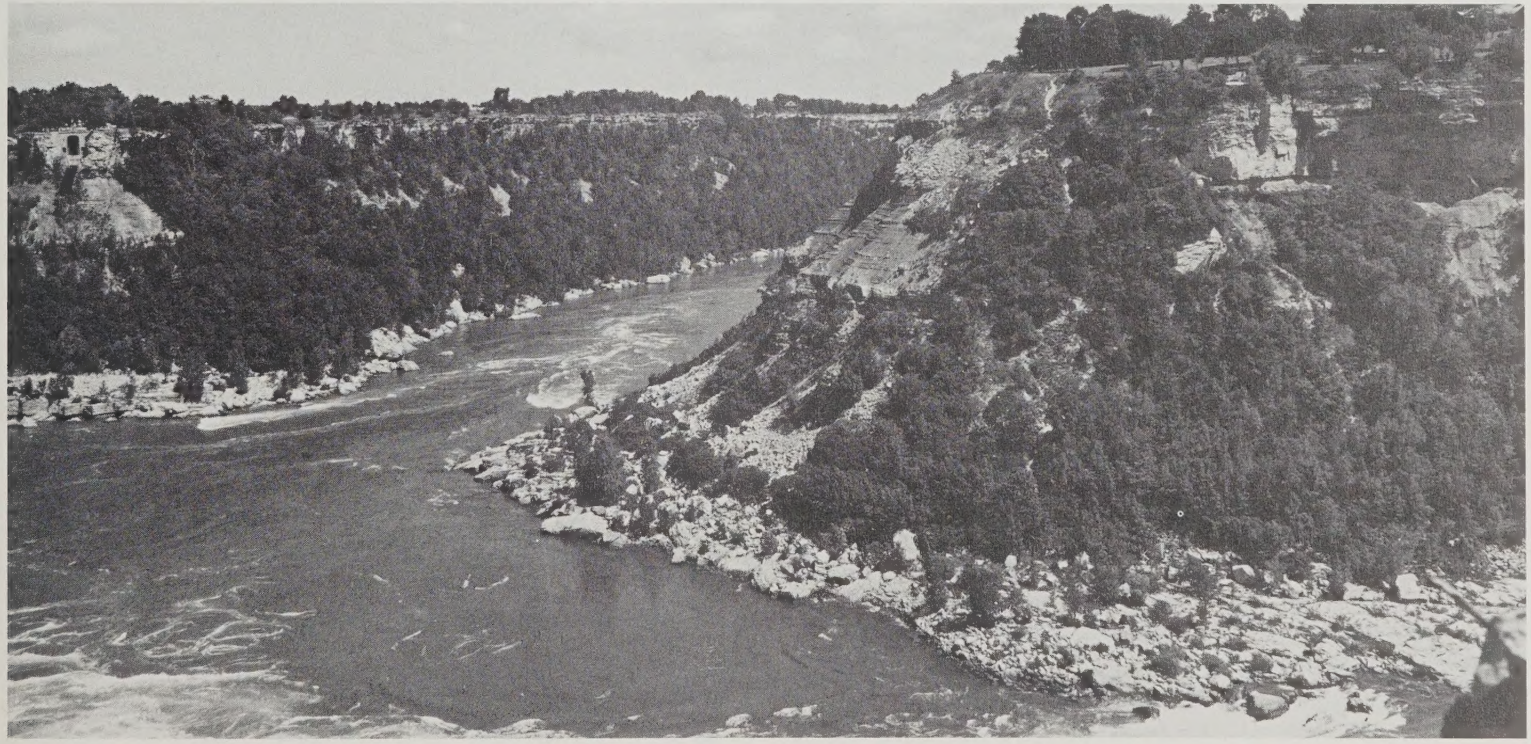
Below Whirlpool Point in New York State, (5), there is a complete exposure of the rocks of the gorge, which can be seen very well from either of the cable car abutments.

From Whirlpool Point itself, which is a state park, there is an excellent view of the Whirlpool and the Whirlpool Rapids Gorge. Walking from the parking lot in the park to the edge of the gorge, you descend what was the bank of the Niagara River when the falls were downstream. From Whirlpool Point it is very apparent that the Whirlpool Rapids Gorge is a continuation of the buried St. David Gorge.

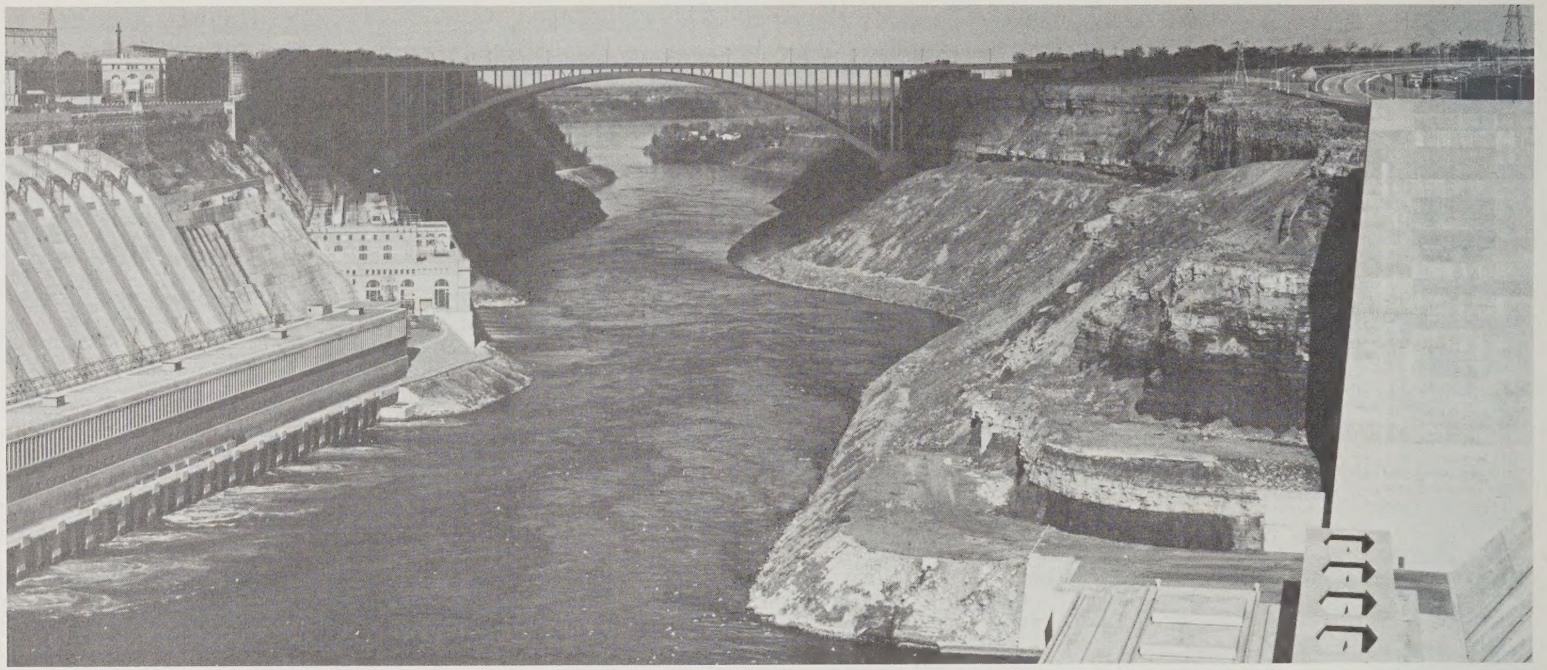
### The Canadian (9) and American Falls (10)

Most of the Upper Great Gorge has been excavated since the birth of Christ, and a historical plaque marks the approximate position the falls had reached when Father Hennepin saw them in 1678. The photograph on page 4 gives some idea of the enormous amount of rock that has been eroded since then—a period of 300 years at the time of writing. It is unlikely that a similar volume of rock will be excavated in the next 300 years because engineering developments have decreased the volume of water discharged over the falls, and the width of the Canadian cataract has been greatly reduced.

To be inspired with the awe that Father Hennepin expressed, you have only to walk through the scenic tunnels



Whirlpool Point in New York State.



The Niagara River—looking north from the Robert Moses Power Plant.

under the falls—reached through Table Rock House (8). From here you can really appreciate the overwhelming power of the cataract, which has been harnessed to make the Niagara Falls region one of the great hydro-electric power development centres of the world. Decades before these developments were even conceived, Charles Lyell wrote in his diary:

> . . .the Falls of Niagara teach us not merely to appreciate the power of moving water, but furnish us at the same time with data for estimating the enormous lapse of ages during which that force operated. A deep and long ravine has been excavated, and the river has required ages to accomplish the task, yet the same region affords evidence that the sum of these ages is nothing, and as the work of yesterday, when compared to the antecedent periods, of which there are monuments in the same district. . .

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## Student Activities

1. The elevation of Lake Superior above sea level is 183 m, and of Lake Ontario, 75.3 m. What percentage of the drop in elevation between the two lakes occurs at the Canadian Falls?
2. Consult Table 3 and determine the drop of the Niagara River at a) the Canadian Falls, b) the American Falls, and c) the Whirlpool Rapids to the Whirlpool.
3. What is the average gradient of the Niagara River between the base of the Canadian Falls and Queenston? The distance between the two points can be measured on Figure 3, and Table 3 gives the elevation at the two points along the river.
4. The shoreline of Lake Iroquois can be identified at the base of the Niagara Escarpment between St. David and Queenston (Figure 3).
   a) Give three other localities around Lake Ontario where the Lake Iroquois shoreline can be observed.
   b) By what route did Lake Iroquois drain to the Atlantic Ocean?

   Consult *Geology of the Great Lakes* by Jack L. Hough.
5. What clue led Charles Lyell to discover the existence of the buried St. David Gorge? Explain.
6. Write a note on the circumstances under which Father Hennepin discovered the falls.
7. Write a note on the role played by the Niagara River during the War of 1812. In whose honour was Brock's Monument erected and why?
8. Trace the history of the hydro-electric power development at Niagara Falls. What were the advantages in locating the modern plants so far north of the falls? You may wish to consult the Ontario Hydro-Electric Power Commission.
9. Using Figure 4, plan a trip to the Niagara River to examine the rocks of the gorge, and to look for evidence regarding the history of the Niagara Gorge.
10. Consult reference books in your school library for information on the following questions:
    a) What is Carbon-14?
    b) How is Carbon-14 used to "date" organic material?
    c) What difficulties are encountered in using Carbon-14 to "date" organic material older than 40 000 to 50 000 years?

The first of a new series of ROM publications entitled ROM ENCOUNTER SERIES, *The Niagara River* provides an absorbing introduction to the geological history of the Niagara River and the interpretations of its origin. Excellent photographs and diagrams highlight the text, and Dr. Tovell suggests several localities where the reader can observe the existing evidence for geological interpretations.

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